

# Managing fodder trees as a solution to human–livestock food conflicts and their contribution to income generation for smallholder farmers in southern Africa

Sebastian Chakeredza, Lewis Hove, Festus K. Akinnifesi, Steven Franzel, Oluyede C. Ajayi and Gudeta Sileshi

---

## Abstract

*Livestock production is an integral part of smallholder farming systems in southern Africa. While goats and sheep play some role in the smallholder farmer household economy, cattle are the predominant livestock species supplying draught power, milk, manure and meat. Production of cattle is based on range grazing. However, the nutritive value of the range is generally low depending on vegetation type and season. With the rapid increase in human population in southern Africa and the increasing need to produce staple food on a sustainable basis, smallholder farmers are increasingly encroaching onto lands formerly reserved for livestock grazing. Therefore, livestock subsisting on the range require supplementation. Conventional bought-in supplements are expensive. Fodder trees and shrubs have been integrated within some farming systems of southern Africa as fodder banks with varying degrees of success. Work carried out in Tanzania, Malawi and Zimbabwe is reviewed to provide evidence on how the fodder tree technology has impacted on livestock production with special reference to smallholder dairy production, human food production and smallholder farmers' income. For the wider adoption of the technology, a synopsis of the different scaling up pathways and approaches adopted by research and development agencies is presented.*

*Keywords:* Smallholder farmers; Livestock production; Fodder shrubs; Livelihoods.

---

## 1. Introduction

Three critical problems confronting agriculture in Sub-Saharan Africa (SSA) include: rapid population growth, decline in per capita production and environmental degradation. The increasing conflict between food production and environmental degradation is defined by experts as a major challenge facing tropical agriculture (Kang and Akinnifesi, 2000). Finding scientific and developmental

innovations that can lead to sustainable livelihoods while minimising or arresting declines in environmental services is a daunting challenge for stakeholders and policy makers, but essential to reducing the poverty and environmental stress that characterise much of the region (Kang and Akinnifesi, 2000; Kwesiga *et al.*, 2003).

In southern Africa, livestock production is an integral part of the smallholder farming system. Cattle are the predominant species supplying draught power, milk, manure and meat. They are also a means of storing capital, of buffering food shortages in years of poor crop harvests and of meeting the social and religious obligations of the farmers (Powell *et al.*, 2004).

Cattle production is dependent on range grazing as the major feed resource. However, due to seasonal fluctuations in feed quality and quantity, cattle are prone to seasonal weight changes with rapid gains in early summer, maintenance of weight in late summer and losses in the dry season which impact on productivity (Otsyina *et al.*, 2004). Some deaths occur during the severe dry season. Additionally, due to rapid population growth, the availability of land for

---

Sebastian Chakeredza is a Senior Education Fellow and Fodder Agronomist at ICRAF Malawi. Email: [Schakeredza@africa-online.net](mailto:Schakeredza@africa-online.net)

Lewis Hove is an Animal Nutritionist at ICRISAT, Bulawayo Zimbabwe. Email: [L.hove@cgiar.org](mailto:L.hove@cgiar.org)

Festus K. Akinnifesi is a Senior Tree Scientist and Regional Coordinator for ICRAF Southern Africa based in Malawi. Email: [f.akinnifesi@africa-online.net](mailto:f.akinnifesi@africa-online.net)

Steven Franzel is a Principal Agricultural Economist for ICRAF, based in Nairobi, Kenya. Email: [S.Franzel@cgiar.org](mailto:S.Franzel@cgiar.org)

Oluyede C. Ajayi is an Agricultural Economist based in ICRAF Malawi. Email: [o.c.ajayi@cgiar.org](mailto:o.c.ajayi@cgiar.org)

Gudeta Sileshi is a Pest Management Specialist based in ICRAF Malawi. Email: [Sileshi@africa-online.net](mailto:Sileshi@africa-online.net)

cattle grazing (Powell *et al.*, 2004) has decreased as cropping extends into areas hitherto used for that purpose. Therefore, under the smallholder production system, grazing cattle require protein supplements, particularly in the dry season. The protein gap is especially acute in the rapidly growing smallholder dairy sector, where farmers can easily increase their cash profits from milk sales by investing in protein supplements. However, bought-in protein supplements are expensive and smallholder farmers are seeking affordable alternatives.

In the last two decades, the World Agroforestry Centre (ICRAF) Southern Africa programme, in partnership with national research and development stakeholders in Malawi, Zambia, Zimbabwe, Mozambique and Tanzania, has been implementing integrated research for development aimed at addressing the problems of low crop production and soil fertility, low cash income, shortages of fuelwood and low livestock production due to fodder shortages. The advances in these innovations have been detailed by Akinnifesi *et al.* (2007b), Nyadzi *et al.* (2003) and Akinnifesi *et al.* (2007a) for soil fertility replenishment based on fertilizer tree systems, fuel wood production using rotational woodlots, and cash income from high-value tree systems, respectively.

This review synthesises the progress that has been made on crop–livestock production systems based on fodder bank innovation. It emphasizes the use of fodder trees and shrubs, herein also referred to as “shrub forages” as protein supplements for livestock in the smallholder dairy sector of southern Africa. Case studies are taken from work conducted by ICRAF in Tanzania, Malawi and Zimbabwe, drawing lessons from the approaches to scaling-up the adoption by smallholder farmers and further research and development needs.

## 2. Evolution of crop–livestock systems in southern Africa

The human population in SSA is currently increasing at the rate of 2.8% per year. Based on projections of population increase, McIntire *et al.* (1992) hypothesized that population pressures on agricultural land in SSA will drive agriculture towards intensification. This is apparent where smallholder farmers no longer practise shifting cultivation and cannot afford to leave part of their farmland fallow to regenerate fertility (Kwesiga *et al.*, 2003). Land is also continually being taken away from livestock grazing in favour of cropping with resultant severe overstocking in certain areas (de Leeuw and Rey, 1995).

One form of intensification due to population pressure is the evolution of crop–livestock systems to serve future needs. The system will be more economically efficient and sustainable than other systems when traditional production methods with low input technology are used, and when scarcity of inputs and poor development of markets continues. Seré and Steinfeld (1996) hypothesized that the following scenarios

may develop at various locations under different population pressures and land resources:

- Scenario 1: Low population pressure plus low annual animal disease stress — the trend will be towards herding.
- Scenario 2: High population pressure — the trend will be towards development of integrated crop–livestock systems.
- Scenario 3: Very high population pressure plus urbanization — development of specialized systems.

These scenarios are all evident today and are directing the evolution of crop–livestock integration in the southern African region. The first scenario involves using fallow periods rather than manure to restore the fertility of the cropping land. Supplemental feeding using, for example, fodder trees and shrubs is not generally economic under these conditions. The free-grazing practices that often prevail in these systems also act as a disincentive to the planting of fodder crops. This system is typical of the Masaai livestock herding in Tanzania.

The second scenario evolves as population pressure makes increased food availability essential and therefore cropping will be intensified. Continuous cropping will lead to a decline in fertility. Although grazing areas will be reduced, animals will still be necessary in the system to provide manure. Since fallowing and pasture will no longer be options for feeding livestock in this scenario, crop residues will start to play an important role as feeds. The smallholder sectors of Zimbabwe and Northern Malawi present typical examples. We propose that under this scenario, strategic application of agroforestry fodder banks will be important.

The third scenario evolves when urban centres become highly populated and markets and improved technologies are developed. Fertilisers replace or supplement manure, tractors replace animal traction and concentrates replace crop residues. The establishment of agroforestry fodder banks could gather prominence under cut-and-carry systems for peri-urban dairies and will be suitable, for example, for the smallholder dairy sector of Malawi.

As the population continues to increase, the efficiency of crop–livestock systems will plateau and attaining a higher level of productivity will require the use of higher input technologies. The demand for animal products will become higher as the incomes of city dwellers increase. This could lead to specialization such as market-oriented peri-urban dairy production and livestock fattening.

The foregoing propositions present varied opportunities for increased livestock production in Southern Africa.

## 3. The place for tree and shrub forages

Tree and shrub forages have been used in livestock production mainly as nitrogen supplements (Osuji and Odenyo, 1997). These form good quality fodder especially for smallholder

farmers with limited land and cash resources. The tree and shrub legumes, once established in the field, have deep roots that enable them to use moisture and nutrients that are beyond the reach of most herbaceous plants (Topps, 1992). Tree legumes also reduce soil erosion, improve soil water conservation, suppress weed growth, replenish soil fertility and provide additional products such as wood for fuel and construction (Nair *et al.*, 1999). The nutritional characteristics of principal tree forages are given in Table 1. The nitrogen content in these selected forages is high and averages 3.71% (23.2% crude protein content).

Poor quality roughages — derived largely from crop residues of sorghum, maize, pearl millet and rice — which form the major source of food for ruminants in Southern Africa are bulky, high in fibre, and low in nitrogen and minerals, resulting in low intakes and poor digestion in the rumen. Fodder research has focused on how to enhance fibre degradation and microbial protein supply by rumen manipulation aimed at maximising these conditions. Use of tree and shrub forages as supplements to poor quality forages has increased nutrient intake, improved body weight gains, and improved survival and milk production by dairy cattle as described in the next section.

### 3.1. Improved food intake

In the work of Mosi and Butterworth (1985) and Smith *et al.* (1990), forage legumes were fed in fixed amounts separately from the poor quality basal diet, given *ad libitum*. In both studies, forage legume supplementation increased total food intake. Supplementation is recommended at levels less than 30–40% of the total diet. Above 40%, substitution of the basal diet takes place.

Forage legumes are relatively good sources of degradable N and fermentable energy and therefore their inclusion in diets is expected to increase the rumen population of cellulolytic microbes (Topps, 1995). Concentrations of rumen ammonia have also been seen to increase following supplementation with forage legumes (Getachew *et al.*, 1994). And, during fermentation, forage legumes also increase the total concentrations of volatile fatty acids (VFAs) without affecting their relative proportions and rumen pH. Ndlovu and Buchanan-Smith (1985) observed that feeding a Lucerne supplement increased the proportion of branched chain volatile fatty acids and suggested that this increase may stimulate the growth of cellulolytic microorganisms.

Creation of this favourable environment increases the rate of degradation of the basal diet in the rumen and leads to increased food intake. Total diet digestibility has also been observed to be improved through ‘positive associative effects’. However for certain forage legumes, the availability of the nitrogenous compounds would be limited by tannins (Mangan, 1988). Tannins exist in condensed or hydrolysable forms at varying levels. Evidence is increasing though that they can have some benefits. Feng Yu and Leng (1991) cited by Devendra (1991) showed that low concentrations

of condensed tannins from *Acacia floribunda* provided protein with protection from rumen degradation.

### 3.2. Improved animal growth performance

Work at the International Livestock Research Institute (ILRI) examined the effect of forage legumes on growth using 40 Friesian × Zebu (Boran) crossbred cattle. In this trial Varviko *et al.* (1992) used wheat middling, cowpea (*Vigna unguiculata*) hay, *Leucaena leucocephala* and Tagasaste (*Chamaecytisus palmensis*) as supplements to native hay. The daily total dry matter intake ranged between 4.0 to 5.0 kg. The results (Table 2) show significant differences between treatments ( $P < 0.01$ ). The diets ranked wheat middling, *Leucaena*, cowpea, Tagasaste, and native hay alone in descending order in terms of metabolizable energy and crude protein intake.

Research work carried out in Zimbabwe by Dzowela *et al.* (1994) with small east African goats established substantial increases in total feed intake and improved weight gains using *A. angustissima*, *L. leucocephala*, *C. calothyrsus* and *Flemingia macrophylla* as supplements to natural pasture hay. Animals on native pasture hay lost weight while those supplemented gained weight ranging from nine (*F. macrophylla*) to 24 g per head per day on *L. leucocephala* and *C. calothyrsus*.

Nherera *et al.* (1998) evaluated three psyllid resistant *Leucaena* species (*L. esculenta*, *L. diversifolia* and *L. pallida*) and *C. calothyrsus* as supplements for growing small east African goats fed on maize stover as the basal diet in Zimbabwe. Total dry matter intake of the goats was significantly higher ( $P < 0.05$ ) when fed with *L. pallida* and *C. calothyrsus* supplemented diets than the basal diet. Weight gain was highest for goats fed on *C. calothyrsus* supplement (44.2 g/day) while those fed on the *L. esculenta*, *L. diversifolia* and *L. pallida* gained 27.5, 37.8 and 40.6 g/day, respectively.

### 3.3. Improved milk production

Work carried out in Kenya with *L. leucocephala* and Napier grass (*Pennisetum purpureum*) as the basal diet by Muinga *et al.* (1993) has established that significant responses in milk yield can occur through forage legume supplementation. The severity of weight losses was also reduced (Table 3). These increases in milk yield should be due to increased supply of nutrients mediated through increased cellulolytic microbial growth leading to increased basal diet degradation and faster digesta outflow.

### 3.4. Economics of using fodder shrubs

Data on the profitability of fodder shrubs in zero-grazing, cut and carry systems are available from Tanzania, Kenya and Uganda. In Tanzania, Otsyina *et al.* (2001) calculated that by using either *L. pallida*, *L. collinsi* or *L. diversifolia*

Table 1. Nutritional characteristics (% of dry matter) of important fodder trees

Shrub forage	Total Nitrogen (N)	ADF	NDF	Lignin	NDF-N	IVDOM	Comments	Reference
<i>Acacia angustissima</i>	3.1	36.7	50.8	14.3	2.1	34.8	Leaf and browseable twigs <10 mm diameter; sundried, Zimbabwe	Dzowela et al. (1995)
<i>Cajanus cajan</i>	3.3	42.0	56.6	16.5	2.7	44.3	Leaf and browseable twigs <10 mm diameter; sundried	Dzowela et al. (1995)
<i>Calliandra calothyrsus</i>	2.0	35.8	46.3	11.4	1.8	33.4	Leaf and browseable twigs <10 mm diameter; sundried	Dzowela et al. (1995)
<i>Flemingia macrophylla</i>	2.4	44.0	59.4	19.3	1.9	25.4	Leaf and browseable twigs <10 mm diameter; sundried	Dzowela et al. (1995)
<i>Leucaena diversifolia</i>	3.63	35.5	39.8	14.1	2.76	0.53	Leaves, shoots and petioles, Zimbabwe	Nherera et al. (1998)
<i>Leucaena esculenta</i>	3.9	30.7	43.7	13.5	3.53	51*	Leaves, shoots and petioles, Zimbabwe	Nherera et al. (1998)
<i>Leucaena pallida</i>	3.48	32.6	37.8	15.0	2.99	53*	Leaves, shoots and petioles, Zimbabwe	Nherera et al. (1998)
<i>Acacia angustissima</i>	3.75	15	34.1	7.2	1.34	51.9	Shade dried leaves, Zimbabwe	Hove et al. (2003)
<i>Calliandra calothyrsus</i>	2.94	14.4	36.0	5.5	1.39	46.0	Shade dried leaves, Zimbabwe	Hove et al. (2003)
<i>Leucaena leucocephala</i>	4.03	17.4	29.2	9.1	1.07	71.4	Shade dried leaves, Zimbabwe	Hove et al. (2003)
<i>Calliandra calothyrsus</i>	4.51	22.0	45.5	—	—	41.6*	Dried shoot material cut after 12 weeks	Kaitho et al. (1993)
<i>Sesbania grandiflora</i>	4.24	—	45.1	—	—	66.9**	Leaves, Thailand	Akksaeng et al. (1989)
<i>Leucaena diversifolia</i>	6.14	28.5–42.4	33.5–46.6	—	—	—	Young leaves	Toruan-Mathius and Suhendi (1992)
<i>Morus alba</i>	2.93	19.23	36.53	—	—	—	Leaves and stems <6 mm diameter, harvested in dry season, South western Nigeria	Madakadze et al. (2004)
<i>Albizia lebbeck</i>	4.10	30.8	35.9	—	—	—	Leaves and stems <6 mm diameter, harvested in dry season, South western Nigeria	Larbi et al. (1998)
<i>Gliricidia sepium</i>	4.06	31.2	38.1	—	—	—	Leaves and stems <6 mm diameter, harvested in dry season, South western Nigeria	Larbi et al. (1998)
<i>Leucaena leucocephala</i>	4.16	29.3	41.7	—	—	—	Leaves and stems <6 mm diameter, harvested in dry season, South western Nigeria	Larbi et al. (1998)

Notes: ADF, Acid detergent fibre; NDF, Neutral detergent fibre; NDF-N, Neutral detergent fibre nitrogen; IVDOM, *In vitro* digestible organic matter; \*Dry matter digestibility; \*\**in vitro* dry matter digestibility.

**Table 2. Daily feed intake (kg dry matter) nutrient consumption (kg), and liveweight gain (g/day) by crossbred steers given native grass hay alone or supplemented with wheat middling, cowpea (*Vigna unguiculata*), *Leucaena leucocephala* or tagasaste (*Chamaecytisus palmensis*) forages, Debre Zeit, Ethiopia.**

Parameter	Diet					Standard error of means
	Hay alone	Wheat middling	Cowpea	Leucaena	Tagasaste	
Hay	4.05	3.78	3.47	3.58	3.38	0.182
Supplement	—	1.26	1.27	1.30	0.88	—
Total	4.05	5.00	4.70	4.83	4.28	0.190
OM	3.63	4.55	4.21	4.34	3.93	0.176
NDF	3.06	3.29	3.32	3.16	3.12	0.152
CP	0.25	0.48	0.37	0.50	0.35	0.016
Daily weight gain	86	411	236	371	62	28.4
ME (MJ)	21.5	38.3	27.7	37.1	25.4	2.37

Notes: OM, organic matter; NDF, neutral detergent fibre; CP, crude protein; ME, metabolizable energy.

Source: Varvikko et al. (1992).

**Table 3. Dry matter intake and milk production (kg/d) of crossbred dairy cows given (*ad libitum*) Napier grass cut at either 1.0 or 1.5 m height and supplemented with 0, 4 or 8 kg fresh *Leucaena leucocephala* per day from 15 to 112 days of lactation, Kenya.**

Leucaena supplementation (kg)	Napier harvest height (m)						Standard error of difference
	1.5			1.0			
	0	4	8	0	4	8	
Intake							
Napier	6.5	6.6	7.1	9.1	9.6	9.3	0.51
Total	6.5	7.8	9.3	9.1	10.7	11.5	0.51
Milk yield	6.1	6.9	7.8	8.5	8.5	8.8	0.55

Source: Muinga et al. (1993).

as substitutes to dairy concentrate, a farmer could save about US\$ 310 per cow per year which would have been used to buy concentrates. In central Kenya, Franzel et al. (2003) found that when Calliandra was used as a substitute to the basal diet, annual net returns increased by US\$ 142. Wambugu et al. (2006) developed a model which incorporates the costs and returns from using *C. calothyrsus* as a supplement or substitute to dairy meal. The elements would differ depending on individual farmer circumstances. The following are the key features of the model and its predictions:

- Many farmers buy commercial dairy meal which can be replaced in part or in whole with the forages.
- Two possible scenarios can be used, either replacing dairy meal with forage legumes (substitution) or adding forage legume to a low quality diet with reduced dairy meal inclusion (supplementation).
- If the forage legume is from the fodder shrub alone, 6 to 10 kg of fresh leaves are given per cow per day.
- The forage legume can be fed either fresh or dry.
- The cost of feeding Calliandra at 6 kg/cow per day is compared with dairy meal at 2 kg/cow per day, which yields about the same milk output.

- In the substitution model, the benefits of using Calliandra, that is, the money saved by not purchasing the equivalent quantity of dairy meal for protein, are compared with the cost, that is, for planting, cutting and feeding it. In the supplementation model, the benefits of increased milk production are compared to the costs of using Calliandra.
- Planting costs, including the costs of purchasing seed and raising bare-root seedlings are about US\$ 6–8 per 500 trees/shrubs.

The results of using Calliandra as a substitute and as a supplement are both very positive. In the substitution scenario, beginning in the second year after planting 500 Calliandra seedlings, a farmer's net income increases by between US\$ 101 up to 122 a year. By using Calliandra as a supplement (6 kg fresh leaves per day) to an existing basal diet (with 2 kg dairy meal), the calculations in East Africa show that a farmer's net income increases by between US\$ 62 and 115. Values vary depending on the price of milk at different locations and whether Calliandra is used as a substitute for dairy meal or a supplement. Other benefits not included in the analysis are the improvement of the cow's condition and the improved butterfat content in the milk gained by using shrub forages, and provision of firewood, fencing, boundary marking and erosion control.

The next section looks at how and where the tree and shrub forages can be established and managed in a typical smallholder set up in southern Africa.

#### 4. Establishment, management and planting niches of fodder trees/shrubs

##### 4.1. Establishment and management of fodder shrubs

The major determinant of the choice of planting material in a particular environment is the tree ideotype. High survival rate, ease of propagation, tolerance to frost and drought, pests and diseases, and periodic pruning, high leaf

**Table 4. Species selection and recommendation domains in East Africa**

Species	Rainfall mm	Altitude (m.a.s.l)	Mean annual temperature (range °C)	Frost tolerance	Soil		
					pH	Drainage	N fixing
<i>Calliandra calothyrsus</i>	>800	0–2200	22–28	None	Acid, neutral, alkaline	Well drained no water logging	Yes
<i>Leucaena diversifolia</i>	1500–3500	500–2000	18–30	Some	Prefers slightly acidic	Prefers slightly acidic	Yes
<i>Leucaena pallida</i>	500–2000	1000–2000	16–21	Some	Neutral, alkaline (>5)	Neutral, alkaline (>5)	Yes
<i>Leucaena trichandra</i>	1100–1800	700–2000	17–22	None	Neutral, alkaline (>5.5)	Neutral, alkaline (>5.5)	Yes
<i>Morus alba</i>	1500–2500	1000–3000	18–30	High	6.0–7.5	Well drained	No
<i>Sesbania sesban</i>	500–2000	100–2500	20–28	Some	Acid, saline, alkaline	Acid, saline, alkaline	Yes
<i>Gliricidia sepium</i>	600–3500	0–1600	15–30	None	4.5–8.0	4.5–8.0	Yes
<i>Chamaecytisus palmensis</i>	600–1600	1500–2500	20–27	High	4.0–8.5	4.0–8.5	Yes

Source: Wambugu *et al.* (2006).

yields and good nutritional value are emphasized in the ideotype. Seed production is important but prolific seeders should be avoided because such shrubs can become invasive weeds. Examples of species selection and recommendation domains are shown in Table 4.

Normally, raising seedlings in nurseries is recommended. The seeds must be soaked in water or scarified to assure good germination and most seeds are sown to a depth of 1–2 times their width. When seedlings or cuttings are used, there should be wide between-plant spacing (preferably 50 × 50 cm or 1 × 1 m). The fodder bank should be kept weed-free for up to 6 months to avoid competition for light, moisture and soil nutrients. Thereafter, the trees are usually able to smother any growing weeds.

Fodder production and accessibility is improved by using double rows of fodder trees at wider spacing (50 cm apart with 1–1.5 m in between double rows) (Paterson *et al.*, 1998). Where land is scarce, farmers may plant fodder shrubs in single rows. Once a fodder bank is established, grass may be allowed to grow in the area between double rows and be managed for fodder provision.

In most cases, the first harvest should be delayed until the trees are 9–21 months. Roshekto (1994) noted that early harvest may damage the trees as it reduces the downward growth of tap roots and therefore it is important to ensure that the fodder bank species have established deep roots and thick trunk diameters (basal diameter of about 3 cm) before the first harvest.

Grazing of the fodder bank can be instituted but dangers of trampling exist. The grazing period should be 1–2 weeks with a rest period of 3–6 weeks. However the vast majority of farmers growing fodder shrubs use them for cut and carry feeding. Important factors to consider include cutting height, cutting frequency and dry season management. This is influenced by temperature, soils, species and plant spacing. The recommended cutting height is between 10–150 cm (Hove, 2004). Exceptions include *Sesbania grandiflora* and *Sesbania sesban* which experience a high degree of mortality when their main stem is cut. The side branches can be harvested, but it should not be completely defoliated

or have the main stem pruned below 150 cm (Roshekto, 1994).

A cutting frequency of 6–12 weeks maximizes fodder yield and quality. This ensures that the fodder maintains high nutritive value and palatability. Repeated cutting over shorter periods decreases longevity of the shrub.

#### 4.2. Planting niches of fodder shrubs in the smallholder sector

With the rapid increase in human and livestock populations and the evolution in the integration of crop–livestock systems, the landholding per family in the southern Africa region is getting smaller. Dzowela *et al.* (1994) estimate that the landholding per family in the southern Africa region is less than 2–3 ha. In such circumstances, farmers cannot block out any area for fodder tree planting. Niches identified should also ensure that the trees serve other purposes like boundary demarcation, soil conservation and fuelwood production to make the technology more attractive to farmers. Niches include planting fodder trees and shrubs:

- As scattered trees in the croplands;
- Below upper-story tree species along boundary lines (Niang *et al.*, 1998);
- As hedges around the farm compound and along pathways. The opportunity exists for replacing unproductive species currently being used as hedges with hedgerows that can yield high quality fodder (Paterson *et al.*, 1998);
- Along terrace edges on sloping land. The fodder hedges help to stabilize the sloping face of the terrace (Paterson *et al.*, 1998);
- Along permanent contour bunds, which are a common feature of gently sloping areas in many parts of southern Africa (Hove, 2004);
- Intercropped with grasses (for example with *Pennisetum purpureum* or *Tripsacum laxum*) in fodder banks. This arrangement will be complementary as the grasses would provide the bulk while the associated shrub forages will provide a nitrogen supplement (Niang *et al.*, 1998);

- The “*ngitili*” (dry-season fodder reserves): This is popular among the Wasukuma agro-pastoralists of Shinyanga region, Tanzania and has proved to be instrumental in range management and forest restoration. The rules for protecting individual and communal *ngitili* are based on traditional village guards and community assemblies. These customary institutions are still important in contemporary natural resource management and have contributed to the successful management of *ngitili*, particularly in adapting to the increase in herd size, which has grown above subsistence level (Kamwenda, 2002; Otsyina et al., 2004);
- In homegardens: A well known example is the *Chagga* homegarden system in northern Tanzania (Fernandes et al., 1984). The system is characterized by a multilayered vegetation structure which is similar to a tropical montane forest with valuable timber trees and other fodder and fuelwood species, shrubs, lianas, epiphytes and herbs (Fernandes et al., 1984). Although the *Chagga* homegarden has been a stable system, it has recently come under pressure from rapid population growth, diminishing land resources and changes in people’s dietary habits (Fernandes et al., 1984; Hemp, 2006);

Establishing shrub forages in these niches will minimise the conflict developing from the need for extra land for crop production as the human and livestock population continue to increase. This should be viewed as a pathway for the greater integration of crop production and livestock rearing in southern Africa. But on the other hand, where free grazing is practised, farmers may prefer to plant fodder shrubs as monocrops in plots, where they can be more easily protected.

## 5. Adoption and impact of fodder bank technology in southern Africa

### 5.1. Tanzania

Systematic work on fodder technology in Tanzania started in 1987 and has been concentrated in the Tabora and Shinyanga areas with dairy farmers (Otsyina et al., 2001). The fodder species were introduced to serve as replacements for the more costly cottonseed meal, which was being used as the major concentrate by dairy farmers.

In both Tabora and Shinyanga areas *L. pallida*, *L. collinsi*, *L. diversifolia*, *A. angustissima* and *G. sepium* were established in fodder banks on farmers’ fields. Farmers were supplied with about 800 seedlings of one or two species. The seedlings were planted on ridges at a spacing of 0.75 m within the ridge and 1.0 m between ridges. Farmers managed the plots and the trees were allowed to establish for one year before cutting back to 0.5 m above ground. Farmers were advised to prune their trees when the re-growth was about 1 metre high. Fodder yields

at each cut were estimated from 20 randomly selected plants from each farmer’s plots.

In Tabora, *L. diversifolia* and *L. pallida* consistently gave high fodder yields ranging from 3.05 to 6.64 t/ha and 0.53 to 0.90 t/ha during the wet and dry seasons, respectively. In Shinyanga, *L. collinsi* gave the highest fodder yield averaging 3.0 t/ha. Animals were stall fed using basal diets composed mainly of natural pastures and standing hay. Dairy supplements included crop residues, maize bran and cottonseed meal. Dry tree leaves from the fodder banks were introduced as a cheaper source of protein substitute for cottonseed meal. The harvested fodder was either offered directly to the cattle or stored for future use by sundrying the leaves for two days and storing them in jute bags. Each dairy cow was given three kg of the dry leaf meal as a supplement to replace the cottonseed meal. The results showed that supplementation with *Leucaena* leaves and maize bran was comparable to cottonseed meal and improved milk production by about 4–5 litres per day over the control based on basal diet plus maize bran only as the supplement.

Cottonseed meal costs about US\$ 9 for a 50 kg bag and lasts for only 10 days per cow. Therefore a farmer would require US\$ 324 per cow per year to buy enough cottonseed meal. It was observed that a fodder bank of 0.21 ha (1 × 1 m spacing; 2100 trees) would sustain a cow for the whole year. By using *Leucaena* leaves, it was calculated, using the procedure in Section 3.4, that a farmer could save about US\$ 310 per cow per year which would have been used to buy concentrates.

These savings allowed farmers to generate regular incomes from milk sales which, in turn, significantly improved their household economies. Family nutrition also improved as some of the milk was being kept for home consumption. Manure quality from the cows fed the legume supplements also improved significantly, thereby positively impacting on crop and vegetable production. Several hundred farmers were reported to be growing fodder shrubs for feeding dairy cows in the Shinyanga and Tabora areas in 2000 (TARDT, 2000). Farmers also grow fodder shrubs in the areas around Arusha, Moshi, Tanga and Mbeya.

### 5.2. Malawi

Livestock production is still a relatively small sector in Malawian agriculture. However, in the Northern region, most smallholder farmers raise animals. Current livestock estimates show that Mzuzu Agricultural Development Division (ADD) which, together with Karonga constitutes the northern region, has 135,000 cattle, 140,000 sheep and goats, 90,000 pigs and 1.465 million poultry. Livestock productivity in this region is low, and meat and milk production do not meet consumer demand. As in other tropical and subtropical regions, local and seasonal shortages of fodder and unbalanced animal nutrition are the main reasons for the low productivity, with protein deficiency being the main factor.

Minae (1993) worked with five dairy farmers evaluating the potential of fodder banks as a supplement for dairy cows and their calves. *L. leucocephala* was grown as a pure stand (1 × 0.4 m spacing) or in association with napier grass (4.5 × 0.4 m for *L. leucocephala* and 0.9 × 0.9 m for napier grass). In the pure stand, 7.9 t/ha of fresh feed was harvested. The farmers used a ratio of 50:50 (*L. leucocephala*: maize bran). Total Leucaena feed per day was about 2 kg per animal. The milk production increased by about 4 kg/animal/day and butterfat content also increased. However, extra labour was needed to cut the fodder. As in the Tanzanian experience, the farmers' returns improved significantly.

In 1998, ICRAF began working with farmers in the Northern region through the establishment of 36 fodder banks. The main problem was low survival rates of the seedlings. It was noted that training given to pioneer farmers was not adequate to ensure optimum tree care and there has also been limited extension support.

Based on the experience in Malawi, ICRAF now targets the fodder bank technology to a high-input high-output dairy production system. The current thrust emphasizes working with smallholder dairy farmers in the Northern, Central and southern regions. The approaches being adopted in working with these farmers are discussed in Section 6.

### 5.3. Zimbabwe

In Zimbabwe, systematic promotion of fodder banks started around 1989 (Dzowela *et al.*, 1994). As in Tanzania and Malawi, shortage of good quality feed, particularly lack of protein has been identified as a major limitation to ruminant livestock productivity in Zimbabwe. Eight tree species were chosen and planted in two contrasting environments (high and low rainfall areas) in 1991. Data were collected on leaf yields (leaf including stems with less than 6 mm diameter). The results are presented in Table 5 from the work of Dzowela *et al.* (1997).

After four years of establishment, *A. angustissima* (Oxford Forestry Institute-OFI accession number 34/88),

*L. Leucocephala*, *G. sepium* and *C. calothyrsus* (OFI 9/89) were the most productive at both sites, producing more than three tonnes of leaf biomass per hectare a year when cut once at the end of the rainy season. However, *L. Leucocephala* is prone to attacks from psyllid which means it could not be recommended in the region. *Gliricidia*, although highly productive, was found to be very sensitive to frost. *Calliandra* did not produce any seed most likely due to the cold conditions.

More provenances of *Acacia*, *Calliandra* and *Leucaena* species were tested since there could be differences in productivity and tolerance to pests and diseases. Those tested (*L. diversifolia*, *L. esculenta* and *L. pallida*) were found to be high yielding and able to withstand psyllid attack. Two further provenances of *C. calothyrsus* were also identified which could produce seed (OFI 10/91 and 12/91). These species have been promoted for use by farmers in Zimbabwe. When used in complete rations for dairy cows, *A. angustissima*, *C. calothyrsus*, *L. Leucocephala* and *Cajanus cajan* produced 11.6, 8.6, 14.4 and 12.8 kg against 15.6 kg milk per cow per day on the conventional diet based on cottonseed meal (Hove *et al.*, 1999). The low performance in the case of animals offered *C. Calothyrsus* could be due to antinutritional factors. Research has continued to assess the use of polyethylene glycol, mixing the fodder shrubs with commercial supplements and mixing tree leaves with complimentary profiles.

Work in Zimbabwe from 1994–95 has concentrated on training farmers on tree management and fodder utilization in smallholder dairy schemes in the country (Hove *et al.*, 2003; Chakoma *et al.*, 2004). The majority of farmers prefer dry leaves because they can be more easily mixed with maize meal and fed to animals.

Using the approach in Section 3.4 for the use of fodder shrubs, farmers surveyed in Zimbabwe have come up with a benefit/cost ratio above 3 for those using the highest quantities of fodder in combination with conventional concentrates. Makaya (2000) reported that farmers are constrained from adopting the fodder bank technology due to their limited resources for protecting the fodder banks from free-ranging

**Table 5. Leaf yields (t/ha) from eight leguminous fodder tree species at Domboshawa and Makoholi, Zimbabwe over three years (1991–1994)**

Species/Provenance	Domboshawa (high rainfall)			Makoholi (low rainfall)		
	1991/1992	1992/1993	1993/1994	1991/1992	1992/1993	1993/1994
<i>Acacia angustissima</i>	1.21	3.52	5.53	0.46	3.26	4.85
<i>Leucaena Leucocephala</i> cv Cunningham	0.21	2.85	5.81	0.54	2.06	5.69
<i>Gliricidia sepium</i>	0.07	3.04	5.04	0.38	2.43	6.34
<i>Flemingia Macrophylla</i>	0.08	3.22	3.75	0.61	2.99	1.82
<i>Calliandra calothyrsus</i> (19678)	0.13	3.53	3.21	0.42	3.09	3.02
<i>Calliandra calothyrsus</i> (19679)	0.07	3.47	2.11	0.41	1.24	3.20
<i>Sesbania sesban</i>	1.71	2.98	0	0.52	1.49	0.92
<i>Sesbania macrantha</i>	0.86	1.03	0	0.52	1.43	0

Source: Dzowela *et al.* (1997). Makoholi, altitude, 1,200 masl, 19°50' S latitude and 30°46' E longitude, average annual rainfall is 565 mm; Domboshawa, altitude = 1,532 masl, 17°36' S latitude and 31°8' E longitude, average annual rainfall is 850 mm.



livestock, inadequate germplasm supply, lack of water for raising seedlings and lack of ration formulation knowledge.

## 6. Pathways for scaling up the fodder bank technology for sustained impact

To leverage the benefits of fodder shrub technology to reach many more farmers and to ensure sustainability of the practice, ICRAF Southern Africa, has adopted a number of approaches. These are often referred to as prongs and are defined as:

- Prong 1. Direct training of farmer trainers and local change agents.
- Prong 2. Training of partner staff (Government and non-governmental organizations).
- Prong 3. Facilitation of farmer exchange visits.
- Prong 4. Support to national extension initiatives on sustainable farming.
- Prong 5. Training of partner staff/farmer trainers by established trained local partners or consultants.
- Prong 6. Support to networking.
- Prong 7. Establishment and/or strengthening of school community links.
- Prong 8. Sensitising policy-makers about the benefits of agroforestry.

Böhringer (2002) discusses the contributions from ICRAF and partners in the different approaches. ICRAF mainly provides germplasm, scientific knowledge, networking and capacity building. Farmers and farmer groups supply land, time, labour and indigenous knowledge. Non-governmental organizations provide grassroots level organization, personnel, operational funds and practical feedback while the government has provided infrastructure, executive power, personnel and tax rebates.

In a preliminary study on the effectiveness and efficiency of prongs (Mulila-Mitti, unpublished), ICRAF Southern Africa has ranked the top three approaches in order as prongs 1 > 2 > 4. Prong 1, the direct training of farmer trainers and local change agents, was the approach used in Tanzania, Malawi and Zimbabwe. Farmer trainers and local change agents were trained on the whole continuum of germplasm selection; establishment of fodder bank; post-establishment care; spacing and design; management; grazing; harvesting and conserving of tree fodder and livestock feeding. The approaches ensure institutionalization of the concept within the national extension systems, educational systems and partner organizations. In the event, therefore, of ICRAF leaving the region, the practice would endure.

Notwithstanding the ranking in the Prongs used by ICRAF, the lessons learnt from implementing an agroforestry programme in southern Africa have shown the following useful ingredients for scaling up of tree-based fodder banks:

- Building skills and knowledge of farmers and local level change agents — for example, through training and exchange visits;
- Building skills of national agricultural research and extension systems;
- Establishing and strengthening school-community links; and
- Investing in sensitization of policy-makers.

Another key contributor to success in scaling up is development of a sustainable seed supply and distribution system (Franzel and Wambugu, 2007). In Kenya, ICRAF and other NGOs helped dozens of private seed suppliers improve their business skills and sell seed to farmers and organizations. Over an eight month period in 2006, 43 seed vendors sold over 2.3 tonnes of seed, sufficient for over 40,000 farmers. In fact, deciding which pathways to use for scaling up new practices depends on the local environment. The approaches cannot be ranked but instead, a blend of the various approaches should be used.

## 7. Conclusions

Livestock production will remain an integral part of the smallholder farming systems of southern Africa for the foreseeable future. The evolution of the crop–livestock system as population pressure rises would require that technologies be adopted to boost the nutritional resource base, if livestock productivity is to be maintained and/or improved. Tree and shrub forages present a number of benefits for the whole smallholder farming system. The majority of smallholder farmers in the region are capable of establishing, managing and incorporating the trees into cattle feeding systems, and exploring niches within the farming lands where the tree and shrub forages can be integrated without compromising crop production. ICRAF has been working closely with farmers and partners to accelerate the adoption of the tree and shrub forage technology, but challenges remain. Indications are that the best scaling up method should be a blend of various approaches, with the major approach depending largely on the local environment. Research should focus on testing fodder shrubs with farmers, monitoring how farmers adapt the practices to their needs and circumstances and assessing which scaling up approaches work best under different circumstances.

## References

- Akinnifesi, F.K., Ajayi, O.C., Sileshi, G., Chirwa, P.W., Kwesiga, F.R., Harawa, R., 2007a. Contributions of agroforestry research and development to livelihood of smallholder farmers in southern Africa: 2. Fruit, medicinal, fuelwood and fodder tree systems. *Journal of Southern Hemisphere Forestry* (in press).

- Akinnifesi, F.K., Chirwa, P.W., Ajayi, O.C., Sileshi, G., Matakala, P., Kwesiga, F.R., Harawa, H., Makumba, W. 2007b. Contributions of agroforestry research to livelihood of smallholder farmers in Southern Africa: 1. Taking stock of the adaptation, adoption and impact of fertilizer tree options. *Journal of Southern Hemisphere Forestry* (in press).
- Akkasaeng, R., Gutteridge, R.C., Wanapat, M., 1989. Evaluation of trees and shrubs for forage and fuelwood in Northeast Thailand. *The International Tree Crops Journal*, 5: 209–220.
- Böhringer, A., 2002. Facilitating the wider use of agroforestry for development in Southern Africa. In: Franzel, S., Cooper, P., Denning, G.L., Eade, D. (Eds.), *Development and Agroforestry: Scaling up the impacts of research*. ICRAF and Oxfam. pp. 35–55.
- Chakoma, C., Franzel, S., Hove, L., Matimati, I., Maasdorp, B.V., 2004. The adoption of fodder trees in Zimbabwe: smallholder farmers' experiences and innovations. In: Rao, M.R. and Kwesiga, F.R. (Eds.), *Proceedings of the Regional Agroforestry Conference on Agroforestry Impacts on Livelihoods in Southern Africa: Putting research into practice*: World Agroforestry Centre (ICRAF), Nairobi, Kenya. pp. 221–233.
- de Leeuw, P.N., Rey, B., 1995. Analysis of current trends in the distribution patterns of ruminant livestock in tropical Africa. *World Animal Review*, 83: 47–59.
- Devendra, C., 1991. Nutritional potential of fodder trees and shrubs as protein sources in ruminant nutrition. *Proceedings of the FAO expert consultation held at Malaysian Agricultural Research and Development Institute (MARDI) in Kuala Lumpur, Malaysia*. Available at <http://www.FAO.org/DOCREP/003/TO632E/TO607.htm#Ch7> Accessed on 05.06.07.
- Dzowela, B.H., Hove, L., Mafongoya, P.L., 1995. Effect of drying method on chemical composition and *in vitro* digestibility of multipurpose tree and shrub fodders. *Tropical Grasslands*, 29: 263–269.
- Dzowela, B.H., Hove, L., Mafongoya, P.L., Maasdorp, B.V., 1997. Recent work on the establishment, production and utilization of multipurpose trees as a feed resource in Zimbabwe. *Animal Feed Science and Technology*, 69: 1–15.
- Dzowela, B.H., Mafongoya, P.L., Hove, L., 1994. *SADC-ICRAF Agroforestry project, Zimbabwe*. 1994 progress report.
- Fernandes, E.C.M., Oktingati, A., Maghembe J., 1984. The Chagga homegardens: A multistoried agroforestry cropping system on Mt. Kilimanjaro (Northern Tanzania). *Agroforestry Systems*, 2: 73–86.
- Franzel, S., Wambugu, C., Tuwei, P., Karanja, G., 2003. The adoption and scaling up of the use of fodder shrubs in central Kenya. *Tropical Grasslands*, 37: 239–250.
- Franzel, S., Wambugu, C., 2007. The uptake of fodder shrubs among smallholders in East Africa: Key elements that facilitate widespread adoption. In: Hare, M.D. and Wongpichet, K. (Eds.), *Proceedings of an International Symposium, Faculty of Agriculture, Ubon Ratchathani University, Thailand: Forages: A pathway to prosperity for smallholder farmers*. pp. 203–222.
- Getachew, G., Said, A.N., Sundstol, F., 1994. The effect of forage legume supplementation and bodyweight gain by sheep fed a basal diet of maize stover. *Animal Feed Science and Technology*, 46: 97–108.
- Hemp, A., 2006. The banana forests of Kilimanjaro: Biodiversity and conservation of the Chagga homegardens. *Biodiversity and Conservation*, 15: 1193–1217.
- Hove, L., 2004. Growing trees for profitable milk production. A manual for farmers and extension staff. World Agroforestry Centre, 37 pp.
- Hove, L., Chakoma, C., Nyathi P., 1999. The potential of tree legume leaves as supplements in diets for ruminants in Zimbabwe. *Proceedings of a joint ZSAP/FAO workshop held in Harare, Zimbabwe, 25th–27th October 1999*. Available at <http://www.Fao.org/DOCREP/004/AC152E/AC152E00.htm> Accessed on 05.06.07.
- Hove, L., Franzel, S., Moyo, P.S., 2003. Farmer experiences on the production and utilization of fodder trees in Zimbabwe. Constraints and opportunities for increased adoption. *Tropical Grasslands*, 37: 279–283.
- Kaitho, R.J., Tamminga, S., Bruchem, J., 1993. Rumen degradation and *in vivo* digestibility of dried *Calliandra calothyrsus* leaves. *Animal Feed Science and Technology*, 43: 19–30.
- Kamwenda, G.J., 2002. Ngitili agrosilvopastoral systems in the United Republic of Tanzania. *Unasylya*, 211(53): 46–50.
- Kang, B.T., Akinnifesi, F.K., 2000. Agroforestry as alternative land-use production systems for the tropics. *Natural Resources Forum*, 24: 137–151.
- Kwesiga, F., Akinnifesi, F.K., Mafongoya, P.L., McDermott, H.H., Agumya, A., 2003. Agroforestry research and development in Southern Africa during the 1990s: Review and challenges ahead. *Agroforestry Systems*, 59: 173–186.
- Larbi, A., Smith, J.W., Kurdi, I.O., Adekunle, I.O., Raji, A.M., Ladipo, D.O., 1998. Chemical composition, rumen degradation and gas production characteristics of some multipurpose fodder trees and shrubs during wet and dry seasons in the humid tropics. *Animal Feed Science and Technology*, 72: 81–96.
- Madakadze, I.C., Hove, L., Makover, V., 2004. The potential of mulberry (*Morus alba L.*) foliage as feed for ruminants in Zimbabwe. In: Rao, M.R. and Kwesiga, F.R. (Eds.), *Proceedings of the Regional Agroforestry Conference on Agroforestry Impacts on Livelihoods in Southern Africa: Putting research into practice*: World Agroforestry Centre (ICRAF), Nairobi, Kenya. pp. 201–207.
- Makaya P., 2000. Fodder banks: Chikwaka dairy farmers give feedback. In: *Living with Trees in Southern Africa*, 4, pp. 17–19.
- Mangan, J.L., 1988. Nutritional effect of tannins in animal feeds. *Nutritional Research Reviews*, 1: 209–231.
- McIntire, J. Bouzart, D., Pingali, P., 1992. *Crop–livestock Interaction in sub-Saharan Africa*. The World Bank, Washington DC, 246 pp.
- Minae, S., 1993. *Annual Report for 1990/91*. Malawi-ICRAF On-farm Agroforestry Research Programme: No 74. 46 pp.
- Mosi, A.K., Butterworth, M.H., 1985. The voluntary intake and digestibility of cereal crop residues and legume hay for sheep. *Animal Feed Science and Technology*, 12: 241–251.
- Muinga, R.W., Thorpe, W., Topps, J.H., 1993. Lactational performance of jersey cows given Napier fodder (*Pennisetum purpureum*) with and without protein concentrates in the semi-humid tropics. *Tropical Animal Health and Production*, 25: 118–128.
- Nair, P.K.R., Buresh, R.J., Mugendi, D.N., Latt, C.R., 1999. Nutrient cycling in tropical agroforestry systems: Myths and science. In: Buk, L.E., Lassoie, J.P. and Fernandes E.C.M. (Eds.), *Agroforestry in Sustainable Agricultural Systems*. CRC Press, Lewis Publ., Boca Raton. pp. 1–31.
- Ndlovu, L.R., Buchanan-Smith, J.G., 1985. Utilization of poor quality roughage by sheep: Effects of alfalfa supplementation on ruminal parameters fibre digestion and rate of passage from the rumen. *Canadian Journal of Animal Science*, 65: 693–703.
- Nherera, F.V., Ndlovu, L.R., Dzowela, B.H., 1998. Utilization of *Leucaena diversifolia*, *Leucaena esculenta*, *Leucaena pallida* and *Calliandra calothyrsus* as nitrogen supplements for growing goats fed maize stover. *Animal Feed Science and Technology*, 74(1): 15–28.
- Niang, A., Styger, E., Gahamanyi, A., Hoekstra, D., Coe, R., 1998. Fodder-quality improvement through contour planting of legume-shrub/grass mixtures in croplands of Rwanda highlands. *Agroforestry Systems*, 39: 263–274.
- Nyadzi, G.I., Otsyina, R.M., Banzi, F.M., Bakeyesa, S.S., Gama, B.M., Mbwambo, L., Asenga, D., 2003. Rotational woodlot technology in northwestern Tanzania: Tree species and crop performance. *Agroforestry Systems*, 59: 253–263.
- Osuji, P., Odenyo, A., 1997. The role of legume forages as supplements to low quality roughages — ILRI experience. *Animal Feed Science and Technology*, 69: 27–38.
- Otsyina, R., Kusekwa, K.L., Shem, M.N., Issae, I.M., Mlengi, W.C., 2004. Traditional fodder conservation and utilization systems in southern Africa: the 'ngitili' in Sukumaland. In: Rao, M.R. and Kwesiga, F.R. (Eds.), *Proceedings of the Regional Agroforestry Conference on Agroforestry Impacts on Livelihoods in Southern Africa: Putting research into practice*: World Agroforestry Centre (ICRAF), Nairobi, Kenya. pp. 173–179.
- Otsyina, R., Kusekwa, M., Mumba, M., 2001. *Fodder trees — Production and utilization in Tanzania*. A paper presented at the International

- workshop on forage demand and adoption by smallholder livestock keepers held at the International Livestock Research Institute (ILRI) Addis Ababa, Ethiopia, June 18–20. 19 pp.
- Paterson, R.T., Karanja, G.M., Roothaert, R.L., Nyaata, O.Z., Kariuki, I.W., 1998. A review of tree fodder production and utilization within smallholder agroforestry systems in Kenya. *Agroforestry Systems*, 41: 181–199.
- Powell, J.M., Pearson, R.A., Hiernaux, P.H., 2004. Crop-livestock interactions in the west African drylands. *Agronomy Journal*, 96: 469–483.
- Roshekto, J., 1994. Fodder bank establishment and management. Agroforestry for the Pacific technologies. Available at [http://www.winrock.org/fnrm/factnet/FACTPUB/AIS\\_web/AIS8.html](http://www.winrock.org/fnrm/factnet/FACTPUB/AIS_web/AIS8.html) Accessed on 11th June, 2007.
- Seré, C., Steinfeld, H., 1996. *World Livestock Production systems: Current status, issues and trends*. Animal Production and Health Paper No 127. FAO. Rome.
- Smith, T., Manyuchi, B., Mikayiri, S., 1990. Legume supplementation of maize stover. In: Dzowela, B.H., Said, A.N., Asrat Wendem-Agenehu, Kategile, J.A. (Eds.), *Utilization of research results on forage and agricultural by-product materials as animal feed resources in Africa. Proceedings of the joint workshop held in Lilongwe, Malawi, 5–9 December, 1988*. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia pp. 303–320.
- TARDT, 2000. *Agroforestry Research and Development in Tanzania: An Overview*. Tanzania Agroforestry Research and Dissemination Team. Shinyanga, Tanzania.
- Topps, J.H., 1992. Potential, composition and use of legume shrubs and trees as fodders for livestock in the tropics. *Journal of Agricultural Science*, 118: 1–8.
- Topps, J.H., 1995. Forage legumes as protein supplements to poor quality diets in the semi-arid tropics. In: Wallace, R.J., Lahlou-Kassi, A. (Eds.), *Rumen Ecology Research Planning*, International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia. pp. 183–192.
- Toruan-Mathius, N., Suhendi, D., 1992. Potential of six cultivars of diploid *Leucaena diversifolia* as animal feed. *Leucaena Research Reports*, 13: 56–58.
- Varvikko, T., Khalili, H., Crosse, S., 1992. Supplementation of native grass hay with cowpea (*Vigna unguiculata*) hay, wilted leucaena (*Leucaena leucocephala*) forage, wilted tagasaste (*Chamaecytisus palmensis*) forage or wheat middling for young Friesian × Zebu (Boran) crossbred steers. *Agriculture Science, Finland*, 1: 247–254.
- Wambugu, C., Franzel, S., Cordero, J., Stewart, J., 2006. Fodder shrubs for dairy farmers in East Africa: Making extension decisions and putting them into practice. World Agroforestry Centre, Nairobi, Kenya; Oxford Forestry Institute, Oxford, UK. 169 pp.